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(54) **Method and equipment for adjusting power amplification in an optical network**

(57) The present invention refers to a method for adjusting a channel power level along the path of a connection in an optical network, said path crossing a plurality of links comprising control means for adjusting said channel power level, the adjustment being achieved in function of:

- connection features,
- physical features of the links,
- control means features of the links,
wherein the adjustment of a channel power level along the path of a connection is achieved by local computations of the channel power level in the plurality of links crossed by the connection.

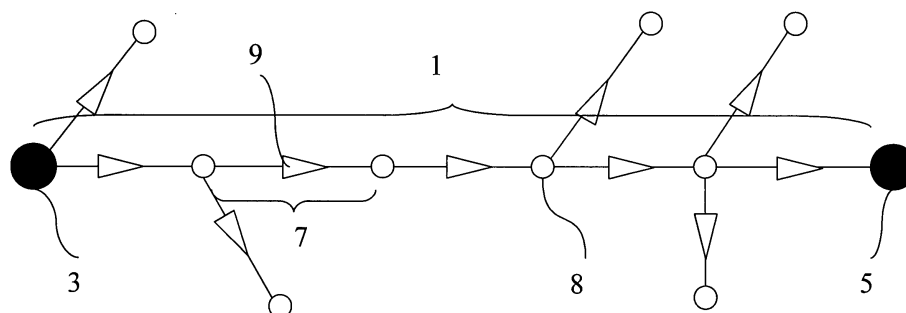


Fig.1

Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to the field of communication networks and in particular to optical communication networks.

[0002] In such networks, an issue is to manage the power level in the links of the network in order to obtain a defined signal quality at the end of a transparent path. Many constraints influence the determination of the power level. Indeed, according to the connection features (length, attenuation of the optical links,...), the power level needs to be adjusted in order to optimize the signal quality at destination. Thus, the objective of the power management is to select for each link along the connection, a power level that minimizes the impairments along the different connections of the link. Such optimization is hard to implement because there are many additional constraints due to the physical features of the equipments and because local constraints may have consequences on the whole network such that a global optimization is required.

SUMMARY OF THE INVENTION

[0003] It is therefore an object of the present invention to provide a method allowing achieving power level adjustment and which is easy to implement.

[0004] Thus, the present invention refers to a method for adjusting a channel power level along the path of a connection in an optical network, said path crossing a plurality of links comprising control means for adjusting said channel power level, the adjustment being achieved in function of:

- connection features,
 - physical features of the links,
 - control means features of the links,
- wherein the adjustment of a channel power level along the path of a connection is achieved by local computations of the channel power level in the plurality of links crossed by the connection.

[0005] According to another embodiment, a power level adjustment cooperation between the plurality of links crossed by the connection is achieved by the transmission of at least one message along the links of the connection, said message comprising at least information concerning the connection and features of the links of said connection.

[0006] According to an aspect of the invention, the information of the message concerning a specific link is updated by the concerned link itself.

[0007] According to an additional embodiment, the control means comprise at least one optical element configured to adjust individual channel power levels.

[0008] According to a further aspect of the invention, the local computations comprise the adjustment of the channel power levels at the output of the links to match target power levels, said target power levels being determined for each link in function of:

- the subsequent link features,
- connection features.

[0009] According to another aspect of the invention, the tolerated difference between an actual power level of a link and the target power level of said link is constrained in function of:

- power available in the link,
- link control means features.

[0010] According to an additional aspect of the invention, an actual power level is modified in function of power status in other links of the connection, said power status being transmitted by at least one message.

[0011] According to a further aspect of the invention, a target power level is modified in function of a signal quality at the end of the connection.

[0012] According to an additional aspect of the invention, the message comprises at least:

- the output power of the previous link along the connection with respect to the link to which the message is currently sent;
- the power status of at least one of the next links along the connection with respect to the link to which the message

is currently sent.

[0013] According to another aspect of the invention, the power status of a link comprises the difference between the actual channel power level and the target power level of said channel.

[0014] According to a further aspect of the invention, the power status of a link comprises the range of power that said link can reach on said channel.

[0015] According to an additional aspect of the invention, said method refers to an iterative and dynamic adjustment of the channel power level along said connection that converges towards an optimal solution.

[0016] According to another aspect of the invention, the iterative and dynamic adjustment corresponds to the minimization of a function $f(P)$ such that:

$$f(P) = \sum_{n=1}^N (P_n - m_n)^2$$

where n is the link index, N the number of links in the connection, m_n is the target power level for the link n , P_n is the actual power level for the link n (both powers being expressed in a logarithmic scale), said minimization being subject to the following constraints:

$$P_n = P_{n-1} + \beta_n$$

where β_n is the gain in the link n and corresponds to the sum of the power losses and power amplification in the link n , and

$$\beta_n^{\min us} \leq \beta_n \leq \beta_n^{\plus}$$

where $\beta_n^{\min us}$ and $\beta_n^{\plus}$ the bounds of the gain for the link n .

[0017] According to an additional aspect of the invention, the vulnerability characterizing parameter of a link influences the channel power level such that, in a connection crossing several links, for a link having a higher vulnerability characterizing parameter, the tolerated difference between an actual channel power level and the target power level is lower than for a link having a lower vulnerability characterizing parameter.

[0018] According to a further aspect of the invention, the iterative and dynamic adjustment corresponds to the minimization of a function $f(P)$ such that:

$$f(P) = \sum_{n=1}^N \left(\frac{1}{\sigma_n^2} \right) (P_n - m_n)^2$$

where n is the link index, N the number of links in the connection, m_n is the target power level for the link n , P_n is the actual power level for the link n (both powers being expressed in a logarithmic scale), $(1/\sigma_n)^2$ the vulnerability characterizing parameter of the link n , said minimization being subject to the following constraints:

$$P_n = P_{n-1} + \beta_n$$

where β_n is the gain in the link n and corresponds to the sum of the power losses and power amplification in the link n , and

$$\beta_n^{\text{minus}} \leq \beta_n \leq \beta_n^{\text{plus}}$$

where β_n^{minus} and β_n^{plus} the bounds of the gain for the link n.

[0019] According to an additional aspect of the invention, the vulnerability characterizing parameter of the link varies in function of at least one parameter in the following list:

- length of the link,
- features of the optical transmission means used in the link such as the type of optical fibers or the type of optical amplifiers,
- link design with respect to the chromatic dispersion.

[0020] According to another aspect of the invention, the vulnerability characterizing parameter of a connection influences the channel power level such that, in a link along the connection, for a channel corresponding to a connection having a higher vulnerability characterizing parameter, the tolerated difference between an actual channel power level and the target power level is lower than for a channel corresponding to a connection having a lower vulnerability characterizing parameter.

[0021] According to a further aspect of the invention, the iterative and dynamic adjustment corresponds to the minimization of a function f such that:

$$f(P) = \sum_{c \in C} \left(\frac{1}{\sigma_c^2} \right) \sum_{n=1} \left(\frac{1}{\sigma_n^2} \right) (P_{c,n} - m_{c,n})^2$$

where $m_{c,n}$ is the target power for the connection c and the link n, $P_{c,n}$ is the actual power for the connection c and the link n (both powers being expressed in a logarithmic scale) and $(1/\sigma_c^2)$ is the vulnerability characterizing parameter of the connection c, subject to the following constraints:

$$\beta_{i,n}^{\text{minus}} \leq \beta_{i,n} \leq \beta_{i,n}^{\text{plus}}$$

where $\beta_{i,n}$ is the gain for the channel i and the link n and $\beta_{i,n}^{\text{minus}}$ and $\beta_{i,n}^{\text{plus}}$ the bounds of the gain for the channel i and the link n and

$$\forall n, \sum_i 10^{\frac{P_{i,n}}{10}} = \sum_i e^{a \cdot P_{i,n}} \leq C_n$$

where C_n is the total available power in the link n (expressed in linear scale), $P_{i,n} = P_{i,n-1} + \beta_{i,n}$ and a is a constant.

[0022] According to another embodiment of the invention, a token is transmitted along the links of the connection and wherein a link is authorized to modify its actual power level and/or its target power value only when authorization is given by the token.

[0023] According to another aspect of the invention, the token is a message and comprises information about the connection, links features and the links power settings.

[0024] The present invention also refers to an optical node comprising:

- processing means for achieving local computation of the channel power levels,
- control means for adjusting channel power levels according to the value determined by the processing means.

[0025] According to another embodiment of the invention, said optical node comprises:

- reception means adapted for receiving a message comprising information about the links of the connection,

- transmission means for transmitting a message to another node of the connection, and wherein the processing means are adapted for reading information received in a message.

[0026] According to a further embodiment of the invention, said optical node comprises:

- updating means adapted for updating the information of the message concerning a link of the connection.

[0027] According to another aspect of the invention, the control means comprise:

- at least one optical element configured to set individual channel attenuations.

[0028] According to an additional aspect of the invention, the control means are adapted to adjust the power gain of the individual channels to a value determined by the processing means.

[0029] According to another aspect of the invention, the control means are adapted to control the individual channel power at the output of the link to a value determined by the processing means.

[0030] The present invention also refers to an optical network comprising a plurality of optical nodes wherein at least one token is transmitted along the connections of the network, said token comprising information about the connection features such as the channel power level along the connection and the power level status of the links along the connection.

[0031] According to another aspect of the invention, an optical node needs to be authorized by the token in order to be allowed to modify its actual power value and/or its target power values.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032]

FIG.1 shows a schematically illustration of a connection in an optical network;

FIG.2 shows a schematically illustration of an optical link;

FIG.3 shows a schematically illustration of the channel power adjustment means in an optical link;

FIG.4 shows a graph representing the bite error rate at the output of a link in function of the input power;

FIG.5 shows a schematically illustration of a portion of an optical network comprising four links and four different connections;

FIG.6 shows a chart of the target power levels for the four connections represented in figure.5;

FIG.7 shows a chart of the power levels for the four connections represented in figure.5 during channel power adjustment;

FIG.8 shows a chart of the power levels for the four connections represented in figure.5 during channel power adjustment;

FIG.9 shows a chart of the power levels for the four connections represented in figure.5 after channel power level adjustment;

DETAILED DESCRIPTION OF THE INVENTION

[0033] As used herein, the term "connection" refers to the transmission of a signal from an ingress node to an egress node through at least one link;

[0034] As used herein, the term "vulnerability characterizing parameter of a connection" refers to a lack of robustness of the connection with respect to degradation or impairments undergone by a signal along the connection. Different parameters may influence said vulnerability characterizing parameter such as

- the length of the connection,
- the modulation format of the connection,
- the bitrate of the connection,
- the format of the error correction code of the connection,
- the physical features of a link such as the type of optical fibers, for example;

[0035] As used herein, the term "vulnerability characterizing parameter of a link" refers to a lack of robustness of a connection along said link with respect to degradation or impairments undergone by a signal along the link. Different parameters may influence said vulnerability characterizing parameter such as

- the length of the link,

- the physical features of the link such as the type of optical fibers for example;

[0036] As used herein, the term "length of a connection" refers to a parameter representative of a quantitative representation of the connection, it can be for example the physical length itself but also the number of links of the connection, the number of spans of the connection or a combination of the number of links or spans and their length;

[0037] As described previously, power management in an optical network is a global issue as a modification in one link of the network may have consequences in the rest of the network due to the multiplicity of connections crossing the network. In order to achieve such global optimization, embodiments of the present invention refer to a distributed method performing a plurality of local computations and leading to a global optimization.

[0038] Fig.1 represents an example of a connection 1 from an ingress node 3 to an egress node 5 through a plurality of links 7 and switching nodes 8, each link 7 comprising at least one optical amplifier 9. Moreover, a link comprises a plurality of channels 15 as represented in Fig.2 corresponding to a plurality of connections 1, each channel 15 having a given wavelength. In embodiments of the present invention, the power level of each channel is adjusted individually, preferably integrated within the switching nodes 8. Such individual adjustment may be achieved, for example, by optical systems 12 as described in Fig.3, which may be disposed within a switching node 8. Optical systems 12 may comprise any individual wavelength attenuation system such as a wavelength selective switch (WSS) or a wavelength blocker (WB) and generally comprises a demultiplexer 11 for separating the different channels 15 which are then transmitted to a range of optical attenuators 13 (for example a set of variable optical attenuators (VOAs)) and then to a multiplexer 17. Said range of optical attenuators 13 can apply individual attenuations to the different channels 15 and therefore adjust individually the power level of each channel 15. The channels are then remultiplexed in the multiplexer 17 in order to be transmitted along a link 7.

[0039] Thus, in order to optimize the signal quality along a connection 1, the power level of the corresponding channel 15 has to be adjusted in each link 7 along the connection 1. To determine this adjustment, target power levels are determined in each link 7. Said target power level corresponds to a power level providing the lowest signal degradation in the subsequent link (in the case when the power level is adjusted at the output of the link).

[0040] Indeed, figure 4 shows a curve that is a representation of the bit error rate (BER) in function of the power level ($P_{1,n}$) on a channel 15 of an optical link 7, both the BER and the power level being represented in decibels (dB). In this curve, we can distinguish three segments.

[0041] First there is a linear segment S1. When the power level is too low, that is lower than P_1 , noise produces impairments and the bit error rate grows linearly with a decrease of power level.

[0042] The second segment S2 between power levels P_1 and P_2 has a parabolic form. This segment S2 is a segment where the error bit rate stays within acceptable limits.

[0043] It can be noted that the bit error rate has a minimum value at a power value P_3 corresponding to the target power level.

[0044] The third segment S3 from power level P_3 increases exponentially with increasing power level. This is due to the fact that when the power level is too high, optical non-linear effects produce impairments in the signal leading to a degradation of the signal and therefore to an increase of the bit error rate.

[0045] The general shape of the curve with the linear S1, parabolic S2 and exponential S3 segments is the same for all channels and links. However, the total value of the bit error rate, in particular the minimum BER at P_3 and the width of segment S2 varies in function of the physical parameters of the link that influence the signal degradation.

[0046] Thus, for a connection 1, the idea is to set in each link 7 of the connection 1, the power level of the corresponding channel 15 to the target power level.

[0047] Nevertheless, additional constraints may prevent the adjustment to the target power levels such as the features of the power distribution means. Thus, a trade-off has to be achieved to adjust the channel power levels along the connection. This trade-off can be represented as the minimization of a cost function f such that

$$f(P) = \sum_{n=1}^N (P_n - m_n)^2$$

where n is the link index, m_n is the target power level for the link n and P_n the actual power level for the link n , both powers being expressed in a logarithmic scale. the function f being subject to the following constraints:

$$P_n = P_{n-1} + \beta_n$$

where β_n is the power gain in the link n which is the parameter that needs to be adjusted. and $\beta_n^{\min us} \leq \beta_n \leq \beta_n^{plus}$ where $\beta_n^{\min us}$ and β_n^{plus} are respectively the lower and upper bounds of the amplification gain in the link n.

[0048] Moreover, the available power in a link 7 is limited such that the actual power level in a link 7 can be modified in order to compensate for a lack or an excess of power in another link 7 of the connection 1.

[0049] Besides, according to the embodiments of the present invention, the determination of the power levels along a connection 1 is achieved in each link 7. Thus, instead of having a centralized computer that determines the power levels for each channel 15 of each link 7 of the network, local computations are achieved in each link 7 of the network. Thus, the local optimizations achieved in each link 7 allow reaching a global optimization in the whole network which optimizes the power adjustment in the network.

[0050] However, to perform a local optimization, a link 7 needs information about the connections 1 performed through said link 7 and about the other links 7 concerned by said connections 1. Thus, messages are transmitted between the links 7 of a connection 1 in order to provide to the links 7 the information required to perform local optimizations. Such messages may be transmitted, for example, according to a resource reservation protocol (RSVP).

[0051] Moreover, in order to reach an optimized solution, the computations along a connection 1 are achieved iteratively. In practice, each time a link 7 receives information from a message comprising new values concerning the external constraints, the link 7 performs a new local computation that takes into account the new constraints values. Then, a new adjustment of the power level in the concerned link 7 is achieved. The value of the power level in said link is updated in the message and the message is then transmitted to at least another link 7 of the connection 1. Thus, as the method is converging, after a few iterations, corresponding to transmissions of a few messages along the connection 1, the channel power levels along the connection 1 are adjusted to an optimized value. Moreover, the method is dynamic such that a modification occurring in the network from an event such as a new connection creation or a connection suppression or a change in propagation features is taken into account in the computations achieved in each link 7.

[0052] Besides, two different embodiments may be distinguished:

In a first embodiment, the adjustment concerns the power amplification gain such that if the input power of a link varies then the output power of said link varies accordingly.

[0053] In such configuration, the required information in order to achieve the local optimization is:

- the input power of the link which corresponds to the output power of the previous link and which is either given by the message or measured locally,
- the power status of the connection in the following links comprising the difference between the actual power level and the target power level of said following links.

[0054] In a second embodiment, the adjustment concerns the output power of the link such that if the input power of a link varies, the local gain is automatically adjusted in order to provide the selected output power. In such configuration, the required information in order to achieve the local optimization is:

- the input power of the link which corresponds to the output power of the previous link and which is either given by the message or measured locally,
- the power status of the connection in the following links comprising:
- the difference between the actual power level and the target power level in said following links of the connection,
- the range of power level reachable by said following links of the connection.

[0055] It has to be noted that the power status of only a limited number of following links can be sufficient if the margin between the actual power level and the bounds of the range of power level of said following links is high enough.

[0056] According to an aspect of the present invention the vulnerability characterizing parameter of a link 7 can be taken into account in the determination of the power level in the link in reducing the tolerated difference between the actual power level and the target power level (also called range of power level) for the links 7 having high vulnerability characterizing parameters.

[0057] In practice, the influence of the vulnerability characterizing parameter of the link 7 is taken into account by introducing said parameter in the function f to minimize such that f becomes

$$f(P) = \sum_{n=1}^N \left(\frac{1}{\sigma_n^2} \right) (P_n - m_n)^2$$

where $(1/\sigma_n)^2$ is the vulnerability characterizing parameter of the link n.

[0058] Furthermore, in a link, additional constraints concerning the other channels 15 and therefore other connections may appear. Indeed, the sum of the channel power levels is limited by the total available power in the link.

[0059] Moreover, according to an aspect of the present invention, the adjustment of the power levels in a link 7 is influenced by the vulnerability characterizing parameter of the connections 1 corresponding to the different channels 15. Thus, the tolerated difference between the actual power level and the target power level (also called range of power level) for a channel 15 corresponding to a connection 1 having a higher vulnerability characterizing parameter is lower than for a channel 15 corresponding to a connection 1 having a lower vulnerability characterizing parameter.

[0060] In practice, the influence of the vulnerability characterizing parameter of the connection is taken into account by introducing said parameter in the function f to minimize such that f becomes

$$f(P) = \sum_{c \in C} \left(\frac{1}{\sigma_c^2} \right) \sum_{n=1}^N \left(\frac{1}{\sigma_n^2} \right) (P_{c,n} - m_{c,n})^2$$

where c is the connection index and $(1/\sigma_c)^2$ is the vulnerability characterizing parameter of the connection c.

[0061] The constraint concerning the total available power has also to be added:

$$\forall n, \sum_i 10^{\frac{P_{i,n}}{10}} = \sum_i e^{a \cdot P_{i,n}} \leq C_n$$

where C_n is the total available power in the link n expressed in linear scale.

[0062] According to another aspect of the present invention, the target power levels can be modified in function of the quality of signal at destination. For example, if after a first adjustment of the channel power levels along the connection the signal quality at destination is much higher than the requested signal quality for this connection, the target power levels along the connection can be reduced in order to save amplification power for other connections or for reducing the total required amount of power.

[0063] In order to synchronize the channel power adjustment along a link and prevent a modification of the power level of two links of a connection at the same time, according to an embodiment of the present invention, a token may be used such that a link needs the authorization of the token in order to modify its actual channel power levels or the target power levels of the different channels.

[0064] In practice, said token may be, for example, a message being transmitted along a connection such that only the link to which the token is attached is able to modify its power adjustment. Moreover, as the other messages, the token may comprise information concerning the connection (length of the connection, number of links in the connection, vulnerability characterizing parameter of the connection,...) and the links of said connection (power status of the links,...) such that the link may achieve power level adjustment in function of the information provided by the token or by previous messages. After adjustment, the link updates the information concerning its power level adjustment in the token and then transmits the token to another link (generally the previous or the next link). Thus, the token may be transmitted back and forth along the connection in order to perform the iterative optimization along the connection which leads to an optimized adjustment of the power levels taking into account the various constraints.

[0065] To better understand the embodiments of the present invention, an example will now be described based on the portion of network presented in figure 5. Said portion of network represents a path comprising four links (A-B, B-C, C-D and D-E) and wherein four connections (C1, C2, C3 and C4) are involved. The table of figure 6 represents the target power levels which have been determined for each connection in each link. The determination of said target power level takes into account the features of the link (number and length of the spans) which are represented in the last two rows and the features of the connections (connection bitrate) which are given in the last column. Furthermore, it has to be noted that the value power values of the different charts are in decibels (dB).

[0066] Then, the local computations will tend to get as close as possible of these target values.

[0067] The table of figure 7 indicates the sum of the target power level for each link and the total available power in the corresponding link.

[0068] One can notice that in the link C-D the sum of the target power levels in the link is larger (of 3dB) than the total available power. Therefore, a power limitation in the link C-D prevents the adjustment of the power level in this link to the target power level. Thus, the power levels in the link C-D have to be reduced to respect the total available power condition. An equitable share of the available power would lead to a reduction of 3dB of each channel. Nevertheless, according the embodiments of the present invention, the power sharing is weighted by a vulnerability characterizing parameter. In the present example, this parameter is function of the number of spans of the connections. Figure 8 shows the adjustment of the power level in the link C-D. Roughly, the connections comprising 9 spans pre-empt an extra dB to the connections comprising only 4 spans.

[0069] Besides, messages comprising the power adjustment in the link C-D are transmitted to the other link of the different connection. Thus, for the connections C1 and C2, the link B-C receives a message which indicates the lack of power in the link C-D for these connections. As the link B-C has an extra power margin, the power levels of the channels corresponding to the connections C1 and C2 in said link are increased in order to compensate for the lack of power in the link C-D. Figure 9 represents the adjustment after power compensation. Moreover, it has to be noted that the power compensation may be extend to several links along the connection if the power margin of one link is not sufficient to compensate the total lack of power. Furthermore, the power compensation may be achieved in any link of the connection (the previous links as well as the following links).

[0070] Thus, the present invention provides a method that allows adjusting channel power levels in each link of an optical network, thus allowing an optimized determination of the power level along a connection leading to an improvement of the transparency of the network. Moreover, the method of the present invention is distributed such that local computations achieve local optimizations and lead to a global optimization. Thus, the impact of an issue in the computation is reduced with respect to a centralized method and the power adjustment can adapt to any modifications in the network topology. Besides, the present invention takes into account the degradation features along the different connections in order to favour the connections having the lowest degradation robustness. Therefore, the optimization of the power level does not compromise the signal quality at destination. Moreover, the measured signal quality at destination can be used in a second order adjustment in order to optimize even more the power adjustment in the network.

Claims

1. Method for adjusting a channel power level along the path of a connection in an optical network, said path crossing a plurality of links comprising control means for adjusting said channel power level, the adjustment being achieved in function of:

- connection features,
- physical features of the links,
- control means features of the links,

wherein the adjustment of a channel power level along the path of a connection is achieved by local computations of the channel power level in the plurality of links crossed by the connection.

2. Method for adjusting a channel power level in accordance with claim 1, wherein a power level adjustment cooperation between the plurality of links crossed by the connection is achieved by the transmission of at least one message along the links of the connection, said message comprising at least information concerning the connection and features of the links of said connection.

3. Method for adjusting a channel power level in accordance with claim 2 wherein the information of the message concerning a specific link is updated by the concerned link itself.

4. Method for adjusting a channel power level in accordance with one of the previous claims, wherein the control means comprise at least one optical element configured to adjust individual channel power levels.

5. Method for adjusting a channel power level in accordance with one of the previous claims, wherein the local computations comprise the adjustment of the channel power levels at the output of the links to match target power levels, said target power levels being determined for each link in function of:

- the subsequent link features,

- connection features.

6. Method for adjusting a channel power level in accordance with claim 5, wherein the tolerated difference between an actual power level of a link and the target power level of said link is constrained in function of:

- power available in the link,
- link control means features.

7. Method for adjusting a channel power level in accordance with claim 2 combined with claim 6 wherein an actual power level is modified in function of power status in other links of the connection, said power status being transmitted by at least one message.

8. Method for adjusting a channel power level in accordance with claim 2 combined with claim 5 or 6 or 7 wherein a target power level is modified in function of a signal quality at the end of the connection.

9. Method for adjusting a channel power level in accordance with claim 2 combined with one of the claims from 2 to 8 wherein the message comprises at least:

- the output power of the previous link along the connection with respect to the link to which the message is currently sent;
- the power status of at least one of the next links along the connection with respect to the link to which the message is currently sent.

10. Method for adjusting a channel power level in accordance with claim 7 combined with one of the claims 7 to 9 wherein the power status of a link comprises the difference between the actual channel power level and the target power level of said channel.

11. Method for adjusting a channel power level in accordance with claim 10 wherein the power status of a link comprises the range of power that said link can reach on said channel.

12. Method for adjusting a channel power level in accordance with one of the previous claims, wherein said method refers to an iterative and dynamic adjustment of the channel power level along said connection that converges towards an optimal solution.

13. Method for adjusting a channel power level in accordance with claim 12, wherein the iterative and dynamic adjustment corresponds to the minimization of a function $f(P)$ such that:

$$f(P) = \sum_{n=1}^N (P_n - m_n)^2$$

where n is the link index, N the number of links in the connection m_n is the target power level for the link n , P_n is the actual power level for the link n ,
said minimization being subject to the following constraints:

$$P_n = P_{n-1} + \beta_n$$

where β_n is the gain in the link n and corresponds to the sum of the power losses and power amplification in the link n , and

$$\beta_n^{\min us} \leq \beta_n \leq \beta_n^{plus}$$

where $\beta_n^{\min us}$ and β_n^{plus} the bounds of the gain for the link n .

14. Method for adjusting a channel power level in accordance with one of the previous claims wherein the vulnerability characterizing parameter of a link influences the channel power level such that, in a connection crossing several links, for a link having a higher vulnerability characterizing parameter, the tolerated difference between an actual channel power level and the target power level is lower than for a link having a lower vulnerability characterizing parameter.

15. Method for adjusting a channel power level in accordance with claims 12 and 14, wherein the iterative and dynamic adjustment corresponds to the minimization of a function $f(P)$ such that:

$$f(P) = \sum_{n=1}^N \left(\frac{1}{\sigma_n^2} \right) (P_n - m_n)^2$$

where n is the link index, N the number of links in the connection m_n is the target power level for the link n , P_n is the actual power level for the link n , $(1/\sigma_n)^2$ the vulnerability characterizing parameter of the link n , said minimization being subject to the following constraints:

$$P_n = P_{n-1} + \beta_n$$

where β_n is the gain in the link n and corresponds to the sum of the power losses and power amplification in the link n , and

$$\beta_n^{\text{minus}} \leq \beta_n \leq \beta_n^{\text{plus}}$$

where β_n^{minus} and β_n^{plus} the bounds of the gain for the link n .

16. Method for adjusting a channel power level in accordance with claim 14 or 15, wherein the vulnerability characterizing parameter of the link varies in function of at least one parameter in the following list:

- length of the link,
- features of the optical transmission means used in the link,
- link design with respect to the chromatic dispersion.

17. Method for adjusting a channel power level in accordance with one of the previous claims wherein the vulnerability characterizing parameter of a connection influences the channel power level such that, in a link along the connection, for a channel corresponding to a connection having a higher vulnerability characterizing parameter, the tolerated difference between an actual channel power level and the target power level is lower than for a channel corresponding to a connection having a lower vulnerability characterizing parameter.

18. Method for adjusting a channel power level in accordance with one of the previous claims wherein a token is transmitted along the links of the connection and wherein a link is authorized to modify its actual power level and/or its target power value only when authorization is given by the token.

19. Optical node comprising

- processing means for achieving local computation of the channel power levels,
- control means for adjusting channel power levels according to the value determined by the processing means.

20. Optical node in accordance with claim 19 wherein said optical node comprises

- reception means adapted for receiving a message comprising information about the links of the connection,
- transmission means for transmitting a message to another node of the connection,

and wherein the processing means are adapted for reading information received in a message.

Amended claims in accordance with Rule 137(2) EPC.

1. Method for adjusting a channel power level along the path of a connection in an optical network, said path crossing a plurality of links comprising control means for adjusting said channel power level, the adjustment being achieved in function of:

- features of the connection,
- physical features of the links,
- features of the control means of the links,

wherein the adjustment of the channel power level along the path of the connection is achieved by local computations of the channel power level in the plurality of links crossed by the path of the connection.

2. Method for adjusting a channel power level in accordance with claim 1, wherein a power level adjustment cooperation between the plurality of links crossed by the path of the connection is achieved by the transmission of at least one message along the links of the connection, said message comprising at least information concerning the connection and features of the links of said connection.

3. Method for adjusting a channel power level in accordance with claim 2 wherein the information of the message concerning a specific link is updated by the concerned link itself.

4. Method for adjusting a channel power level in accordance with one of the previous claims, wherein the control means comprise at least one optical element configured to adjust individual channel power levels.

5. Method for adjusting a channel power level in accordance with one of the previous claims, wherein the local computations comprise the adjustment of the channel power levels at the output of the links to match target power levels, said target power levels being determined for each link in function of:

- the subsequent link features,
- features of the connection.

6. Method for adjusting a channel power level in accordance with claim 5, wherein the tolerated difference between an actual power level of a link and the target power level of said link is constrained in function of:

- power available in the link,
- features of the control means of the link.

7. Method for adjusting a channel power level in accordance with claim 2 combined with claim 6 wherein the actual power level is modified in function of power status in other links of the connection, said power status being transmitted by at least one message.

8. Method for adjusting a channel power level in accordance with claim 2 combined with claim 5 or 6 or 7 wherein the target power level is modified in function of a signal quality at the end of the connection.

9. Method for adjusting a channel power level in accordance with claim 2 combined with one of the claims from 2 to 8 wherein the message comprises at least:

- the output power of the previous link along the connection with respect to the link to which the message is currently sent;
- the power status of at least one of the next links along the connection with respect to the link to which the message is currently sent.

10. Method for adjusting a channel power level in accordance with claim 7 combined with one of the claims 7 to 9 wherein the power status of a link comprises the difference between the actual channel power level and the target power level of said channel.

11. Method for adjusting a channel power level in accordance with claim 10 wherein the power status of a link comprises the range of power that said link can reach on said channel.

12. Method for adjusting a channel power level in accordance with one of the previous claims, wherein said method refers to an iterative and dynamic adjustment of the channel power level along said connection that converges towards an optimal solution.

13. Method for adjusting a channel power level in accordance with claim 12, wherein the iterative and dynamic adjustment corresponds to the minimization of a function $f(P)$ such that:

$$f(P) = \sum_{n=1}^N (P_n - m_n)^2$$

where n is the link index, N the number of links in the connection m_n is the target power level for the link n , P_n is the actual power level for the link n , said minimization being subject to the following constraints:

$$P_n = P_{n-1} + \beta_n$$

where β_n is the gain in the link n and corresponds to the sum of the power losses and power amplification in the link n , and

$$\beta_n^{\min us} \leq \beta_n \leq \beta_n^{\plus}$$

where $\beta_n^{\min us}$ and $\beta_n^{\plus}$ the bounds of the gain for the link n .

14. Method for adjusting a channel power level in accordance with one of the previous claims wherein the vulnerability characterizing parameter of a link influences the channel power level such that, in a connection crossing several links, for a link having a higher vulnerability characterizing parameter, the tolerated difference between an actual channel power level and the target power level is lower than for a link having a lower vulnerability characterizing parameter.

15. Method for adjusting a channel power level in accordance with claims 12 and 14 in combination, wherein the iterative and dynamic adjustment corresponds to the minimization of a function $f(P)$ such that:

$$f(P) = \sum_{n=1}^N \left(\frac{1}{\sigma_n^2} \right) (P_n - m_n)^2$$

where n is the link index, N the number of links in the connection m_n is the target power level for the link n , P_n is the actual power level for the link n , $(1/\sigma_n)^2$ the vulnerability characterizing parameter of the link n , said minimization being subject to the following constraints:

$$P_n = P_{n-1} + \beta_n$$

where β_n is the gain in the link n and corresponds to the sum of the power losses and power amplification in the link n , and

$$\beta_n^{\text{minus}} \leq \beta_n \leq \beta_n^{\text{plus}}$$

where β_n^{minus} and β_n^{plus} the bounds of the gain for the link n.

16. Method for adjusting a channel power level in accordance with claim 14 or 15, wherein the vulnerability characterizing parameter of the link varies in function of at least one parameter in the following list:

- length of the link,
- features of the optical transmission means used in the link,
- link design with respect to the chromatic dispersion.

17. Method for adjusting a channel power level in accordance with one of the previous claims wherein the vulnerability characterizing parameter of a connection influences the channel power level such that, in a link along the connection, for a channel corresponding to a connection having a higher vulnerability characterizing parameter, the tolerated difference between an actual channel power level and the target power level is lower than for a channel corresponding to a connection having a lower vulnerability characterizing parameter.

18. Method for adjusting a channel power level in accordance with one of the previous claims wherein a token is transmitted along the links of the connection and wherein a link is authorized to modify its actual power level and/or its target power value only when authorization is given by the token.

19. Optical node comprising

- processing means for achieving local computation of channel power levels,
- control means for adjusting said channel power levels according to the channel power levels computed by the processing means.

20. Optical node in accordance with claim 19 wherein said optical node comprises

- reception means adapted for receiving a message comprising information about the links of the connection,
- transmission means for transmitting a message to another node of the connection, and wherein the processing means are adapted for reading information received in a message.

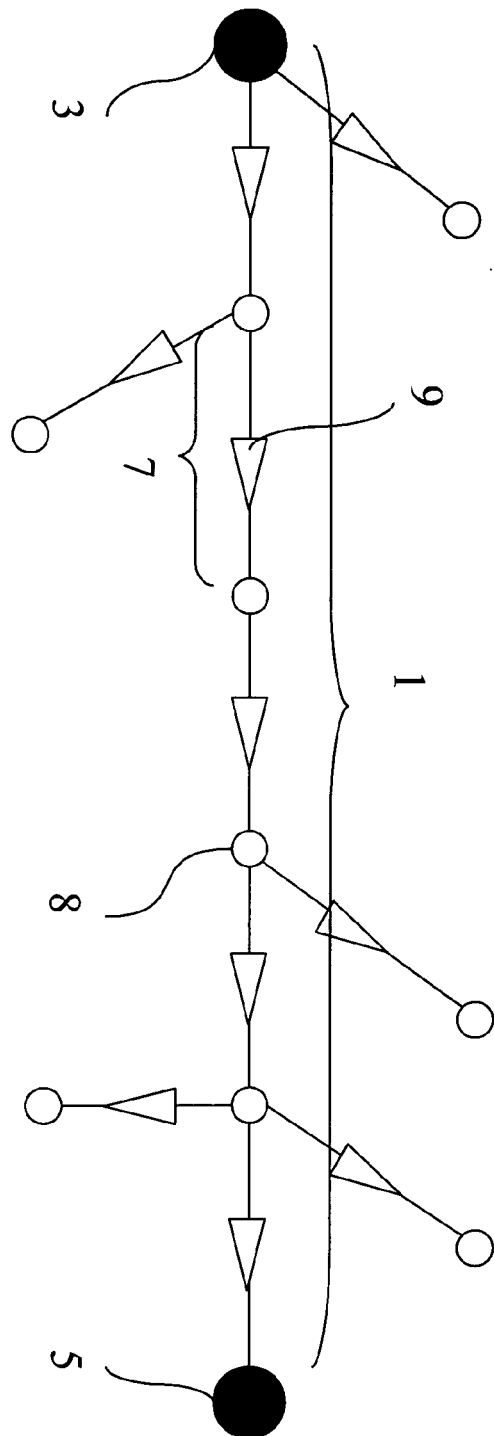


Fig. 1

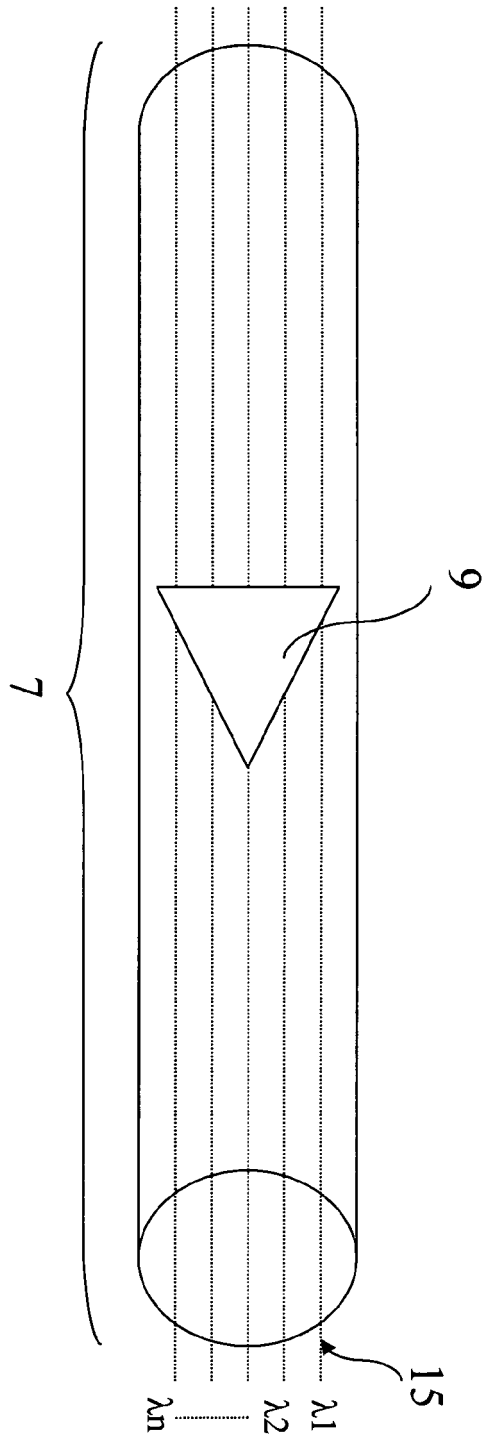


Fig.2

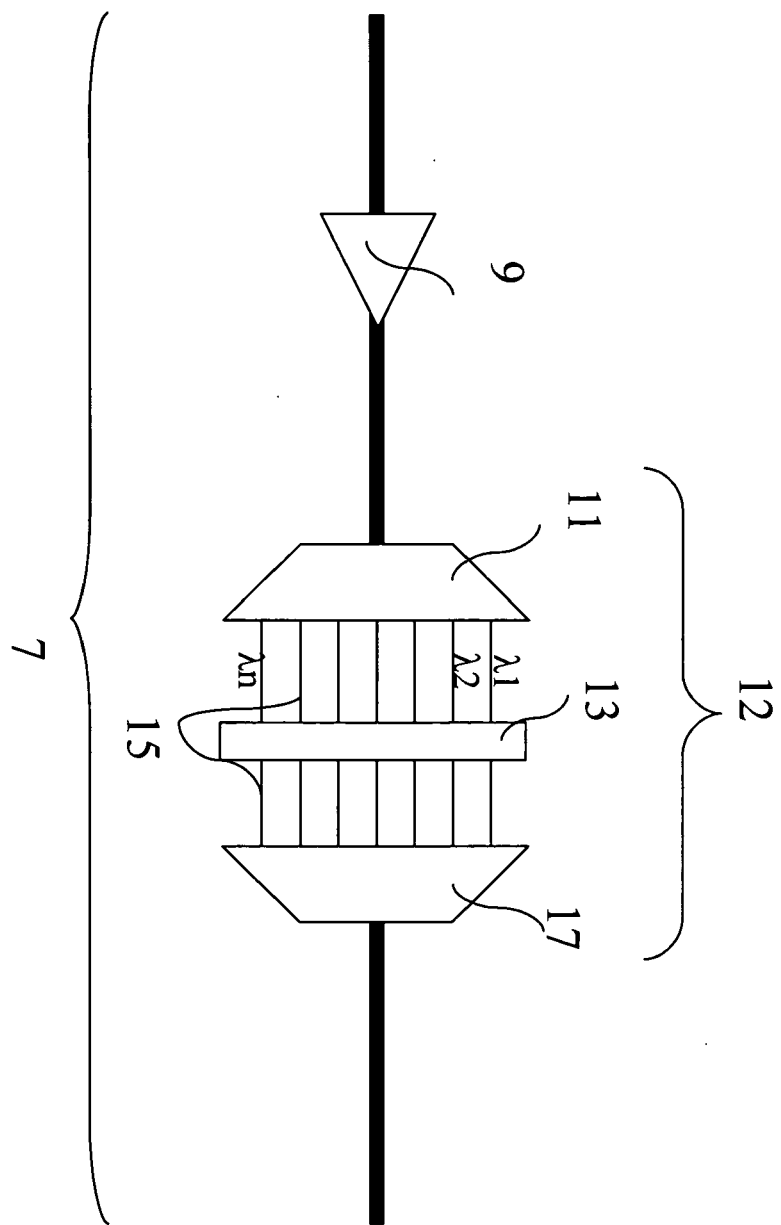


Fig.3

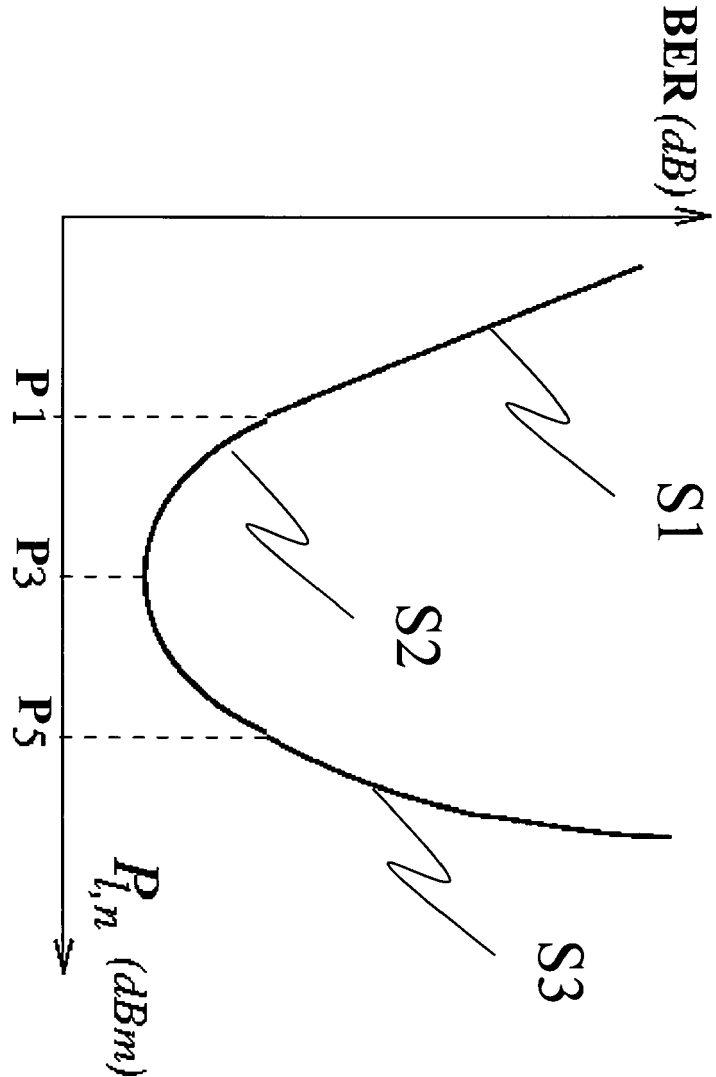


Fig.4

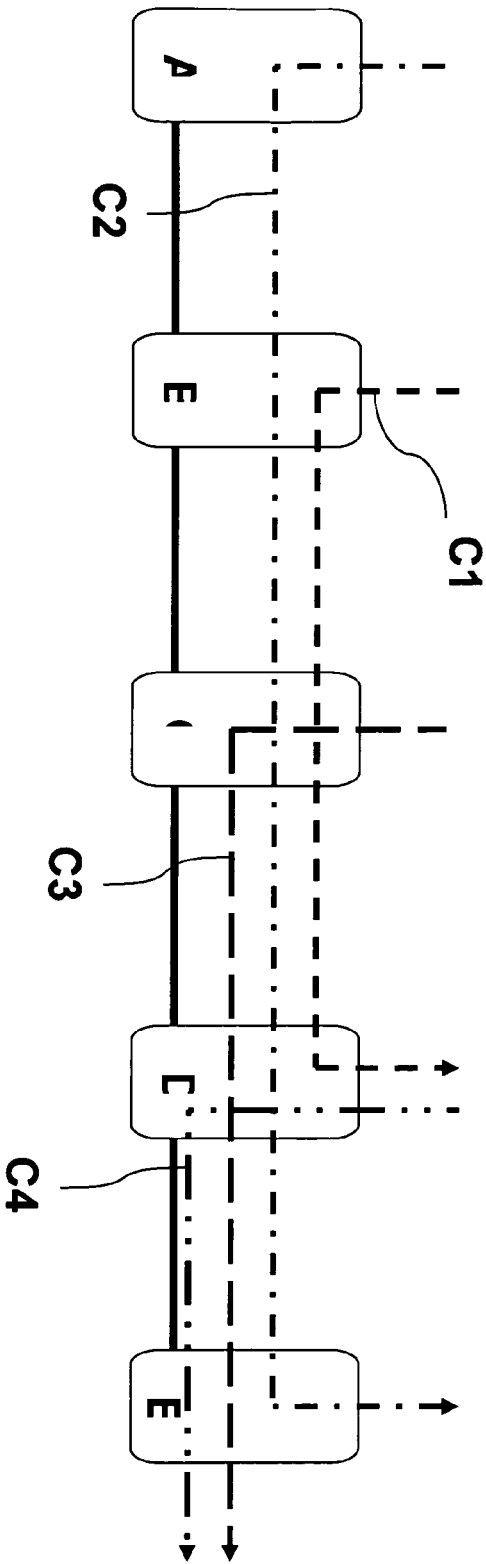


Fig.5

Links Connections	A-B	B-C	C-D	D-E	Connectio n bitrate
C1		1	3		10Gb/s
C2	1	1	3	2	10 Gb/s
C3			0	-1	2.5 Gb/s
C4				2	10 Gb/s
Number of span	3	3	1	2	
Length of spans	80 km	80 km	110 km	100 km	

Fig.6

Links Connections	A-B	B-C	C-D	D-E
C1		1	3	
C2	1	1	3	2
C3			0	-1
C4				2
Sum of target powers	1	4	7	6
Total available power	4	6	4	6

Fig.7

Links	A-B	B-C	C-D	D-E	Total number of spans
Connections					
C1		1	-2		4
C2	1	1	1	2	9
C3			-2	-1	9
C4				2	4
Sum of target powers	1	4	4	6	
Total available power	4	6	4	6	

Fig.8

Links Connections	A-B	B-C	C-D	D-E	Total number of spans
C1		2.5	-2		4
C2	1	1.5	1	2	9
C3			-2	-1	9
C4				2	4
Sum of target powers	1	5	4	6	
Total available power	4	6	4	6	

Fig.9

Application Number
EP 09 29 0408

DOCUMENTS CONSIDERED TO BE RELEVANT					
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)		
X	US 2004/208531 A1 (BOSLOY JONATHAN L [CA] ET AL) 21 October 2004 (2004-10-21) * abstract * * paragraph [0001] - paragraph [0014] * * paragraph [0028] - paragraph [0032] * * paragraph [0047] - paragraph [0050] * * paragraph [0052] - paragraph [0063] * -----	1-20	INV. H04J14/02		
			TECHNICAL FIELDS SEARCHED (IPC)		
			H04J		
The present search report has been drawn up for all claims					
Place of search Munich		Date of completion of the search 23 October 2009	Examiner Chauvet, Christophe		
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document					

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 09 29 0408

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23-10-2009

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US 2004208531 A1	21-10-2004	NONE	

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